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Work Compatibility of Excavator Komatsu PC400 with Hino 500 FM 320 TI Transport Equipment in Coal Mining Activities in North Pit Muara Tiga Besar 1 PT Bukit Asam, Tbk.Tanjung Enim, South Sumatra.

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Abstract. *PT Bukit Asam (Persero) Tbk is a State-Owned Enterprise (SOE) established on March 2, 1981 located in Tanjung Enim, South Sumatra. The purpose of production activities is to produce minerals that have a price or selling value, in coal production activities there are two productions that can be done, namely coal production and overburden production. PT Bukit Asam Tbk. applies the open pit mining method. In coal getting activities, PT Bukit Asam Tbk. uses Komatsu PC400 excavating equipment and DT HINO 500 transportation equipment, while in overburden excavation activities PT Bukit Asam Tbk. uses Komatsu PC2000 excavating equipment and Komatsu HD785 transportation equipment. Apart from loading and hauling excavation equipment as the main mining equipment, there are also supporting equipment such as motor graders, bulldozers, water tanks and fuel tanks to get optimal and maximum results from production. In coal mining activities in the Muara Tiga Besar Mining area, PT Bukit Asam Tbk. company uses Komatsu PC 400 for coal getting and Komatsu PC2000 for overburden activities, while for transportation equipment in the form of Dump Trcuk HINO 500 FM 320 TI for coal getting and HD 785 for overburden activities. The results of observations in the field obtained the productivity value of the PC400 digging tool for coal getting is 257.73 tons / hour, while for DT HINO 500 FM 320 TI for coal getting is 72.46 tons / hour.*

Keywords: *Production, Coal, Dump Truck, excavator, Overburden*

1.Introduction

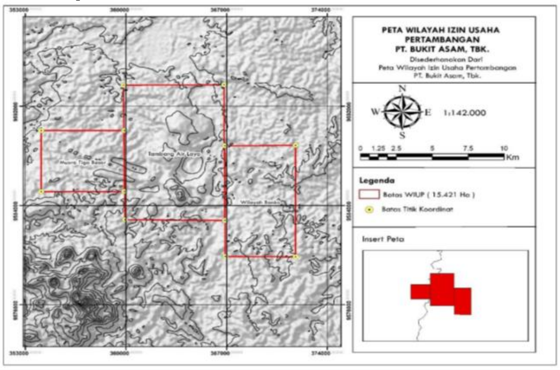
PT Bukit Asam Tbk. is a company that carries out activities in the mining sector by mining coal. PT Bukit Asam Tbk. is located in Lawang Kidul Subdistrict, Tanjung Enim Village, Muara Enim Regency, Palembang Province, South Sumatra. PT Bukit Asam Tbk. applies the open-pit mining method. In coal mining activities PT Bukit Asam Tbk. uses the help of Komatsu PC400 excavators and DT HINO 500 transporters, while in the excavation of overburden PT Bukit Asam Tbk. uses Komatsu HD785 transportation and Komatsu PC2000 excavators. Apart from excavator loading and transportation as the main mining equipment, there are also supporting equipment such as motor graders, bull dozers, water cars and oil cars to get optimal and maximum results from the production carried out.

In a mining process, production is an important activity within the scope of mining. The purpose of production activities is to produce goods with a marketable price or value. In the context of barrel production in mining activities, namely barrel production and overburden production. To ensure that equipment can be used as efficiently as possible and has a high efficiency threshold to meet production targets, proper maintenance must be carried out (Octova, 2021).

The combination of excavator and haulage transportation, the working efficiency of the equipment, which is affected by the endurance time, and the working harmony of the mechanical equipment, which is affected by the circling time, vertical distance, and other factors, are some of the factors that need to be considered in this issue. To ensure that excavators and haulers work perfectly together, it is important to know the productivity of Komatsu PC400 excavators with DT HINO 500 FM 320 TI haulers.

2.Research Location

2.1 Map of WIUP PT Bukit Asam Tbk.



Source: Geological and exploration engineering work unit of PT Bukit Asam, Tbk.

Fig 1.. Map of WIUP PT Bukit Asam Tbk.

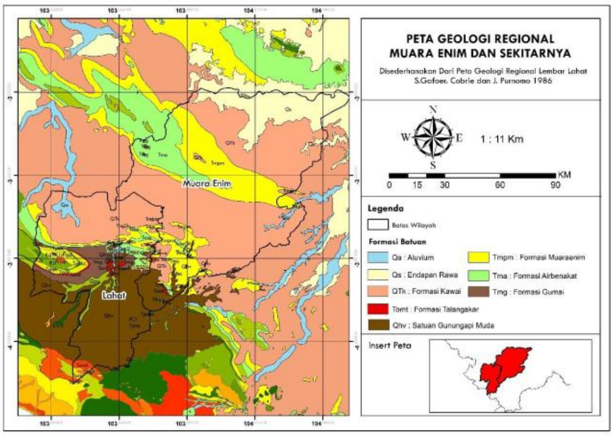
A company in the mining industry, PT Bukit Asam Tbk, draws resources from extracting coal. In Palembang Province, South Sumatra, Tanjung Enim Village, Muara Enim Regency, Lawang Kidul District is the location of PT Bukit Asam Tbk. Open pit mining is used by PT Bukit Asam Tbk

PT Bukit Asam Tbk. uses Komatsu PC400 digger and loader and DT HINO 500 hauling equipment for coal mining operations, while PT.Wilayah Izin Usaha Pertambangan (WIUP) PT Bukit Asam in open mining method, Tbk has Tanjung Enim Mining Units consisting of Muara Tiga Besar, Bangko Barat, Air Laya with the position of the Coordinates of the boundaries of the Mining Business License Area (WIUP) PT Bukit Asam, Tbk.

2.2 Regional Geological Conditions

The regional geology of the South Sumatra Basin generally describes it as a Tertiary-era basin surrounded by the Semangko Fault and the Bukit Barisan Mountains. The main tectonic activity on the island of Sumatra is faulting. Outcrops of Pre-Tertiary mountain ranges in the Bukit Barisan to the southwest and the Sunda Shelf to the northeast surround the South Sumatra Basin which covers 330 x 510 km2, an arc basin, bordered by the Lampung Tiga Puluh Plateau to the northwest and Lampung to the southeast, which divides it from the Central Sumatra Basin to the south (Wisnu & Nazirman, 1997).

In the South Sumatra Basin area, the Tertiary rocks are divided into three parts or cycles according to the time period of uplift and erosion. The layers are the first layer, which is fluviatile to lacustrine dated to the Eocene, Oligocene, or Miocene (Lahat and Talangakar Formations); the second layer, which is marine swamp dated to the Middle Miocene (Baturaja and Gumai Formations); and the third layer, which is marine shrinkage dated to the Late Miocene-Plistocene (Airbenakat, Muaraenim, and Kasai Formations).



Source: (Gafoer et al., 1986).

Fig 2. Regional geological map of Muara Enim and its surroundings.

2.3 Statigrafi Regional

In general, the regional stratigraphy of the Tanjung Enim area is found in the stratigraphic column. Where in it there are coal layers that are seen in several layers, namely: first is the Keladi Layer, second is the Merapi Layer, third is the Petai Layer, fourth is the Suban Layer and Mangus Layer. Each layer is named as layer A, layer B, layer C and layer D, as well as 7 hanging layers in the area.

2.3.1 Benakat Water Formation

During the Middle Miocene, during the regression phase and at the end of deposition of the Gumai Formation, the Air Benakat Formation was deposited (Bishop, 2001). During this regression phase, deposition occurred in a shallow marine environment, which at the end of the first regression cycle turned into deltaic plains and coastal swamps. The formation consists of bluish gray sandstone, gray-white mudstone with fine sandstone inserts, and local glauconite containing lignite and tuff in the upper part. The central part of the formation is rich in foraminiferal fossils. The thickness of the formation is estimated to be between 1000 and 1500 meters.

2.3.2 Muara Enim Formation

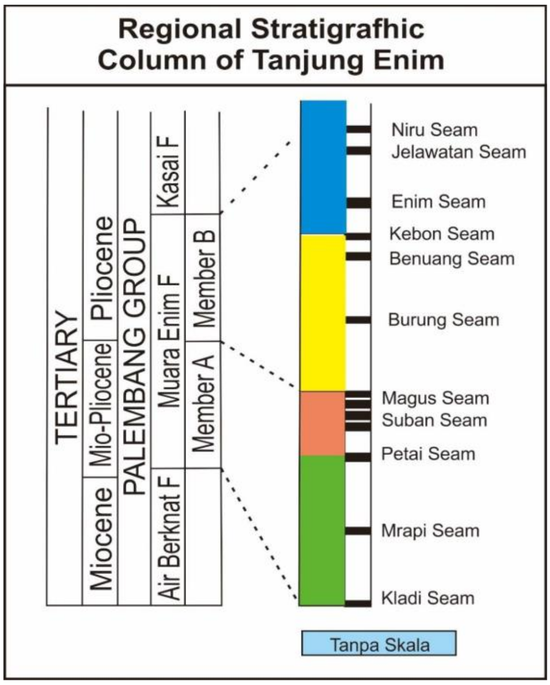
The second regression cycle, from deposition of shallow marine processes to continental sands, deltas and mudstones, is represented by this formation, which was deposited between the late Miocene and Pliocene. The absence of glauconite sandstones and the buildup of thick coal sections distinguish the second regression cycle from the first depositional cycle (Air Benakat Formation). Large coal deposits formed from the first deposition, which occurred in a coastal plain wetland environment, halfway across the southern part of the basin in South Sumatra province.

2.3.3 Kasai Formation

Deposition of this layer occurred between the Pliocene and Pleistocene epochs. Its deposition was a consequence of the fold uplift that occurred in the basin, as well as erosion from the uplift of the Thirty Mountains and Bukit Barisan. After the first indication of late uplift of the Bukit Barisan Mountains, which began in the late Miocene, deposition began. Tuffaceous sandstones initially appear at the junction of this formation with the Muara Enim formation. Volcanic products are the main feature of the deposits of this third regression cycle. Continental sandstones, clays, and pyroclastic debris form the Kasai Formation. The marine shrinkage cycle was broken by this development. Tuffaceous sandstones form the lowest part, with some

2.3.4 Andesite

This rock improves the quality of coal by breaking through the layers of the Muara enim Coal Formation. These outcrops are located on the west side of Pulau Panggung at Bukit Asam and Bukit Malaluteh. The Kasai Formation rocks are intruded by andesite rocks at Bukit Mataluteh. The field appearance consists of boulders measuring three to four meters (insitu). These andesite rocks are thought to be retas (embankments). The texture of the andesite rock is porphyritic, dense, and dark gray in color. Its mineral composition consists of pyroxine, plagioclase, hornblende, and other dark minerals. The age of this soil-forming rock is Plistocene.

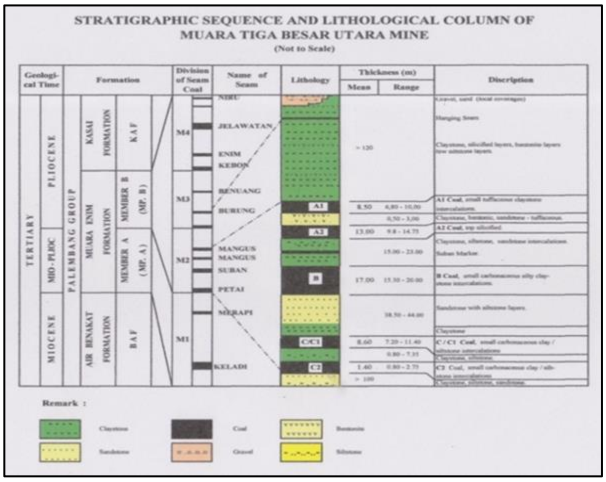


Source: detailed exploration work unit of PT Bukit Asam, Tbk..

Fig 3. Regional Statigraphy of Tanjung Enim.

2.4 Stratigraphy of North Muara Tiga Besar Mine

In general, the stratigraphic column consisting of a series of formations in the Muara Enim location of the three coal sections, namely the petai layer, mangus layer, and suban layer, shows in general the layers that exist in the Muara Tiga Besar Utara (MTBU) area. Each of these layers has an insertion layer, which is a layer of sedimentary rock in the form of silt loam to pasiran. The stratigraphic sequence is as follows: Overburden, A1 Coal Layer (Upper Mangus), A1 - A2 Interburden Layer, A2 Coal Layer (Lower Mangus), A2 - B Interburden Layer, B Coal Layer (Suban), B - C Interburden Layer and C Coal Layer (Petai).



Source: PTBA Detailed Exploration Work Unit.

Fig 4. North Muara Tiga Besar Statigraphy.

3.Theoretical Review.

Loading is the act of picking up and loading material into a conveyance, stockpile, container, or material flow arrangement (hopper, bin, feeder, etc.). Loading also refers to loading equipment, such as power shovels, backhoes, or drag lines. This definition is taken from the Encyclopedia of Mining, Third Edition (2000). If the distance transported is less than 100 meters, DTs, motor scrapers, wheel loaders, or bulldozers can be used in mining (Tenriajeng, 2003).

Loading is the process of loading excavated material involving the placement of power shovels, backhoes, drag lines, and other equipment onto heavy haulers.

Hauling is the process of transporting material that has been excavated, known as hauling. While coal is moved using hauling equipment to the stockpile, overburden material is moved to the dump (Indonesianto, 2005).

The factors that can affect the productivity of excavation and transport equipment in mining areas include:

3.1 Material Type.

a. Easy to dig and not hard (easy digging)

Examples: topsoil, sand, sandy-clay, clayey sand.

b. Medium or intermediate digging

Example: wheathered rocks, clay.

c. Hard excavation or hard soil or rock types.

Examples: conglomerate, breccia, shale, compacted material.

d. Very hard excavation or hard rock types

- Assisted by blasting before it can be excavated.

3.2 Bucket Fill Factor.

Fill factor is the ratio between the percentage of volume that can be loaded into the loading bay compared to its theoretical capacity.

$$BFF = \frac{Va}{Vt} x\ 100\%$$

Description:

BFF = Bucket Fill Factor

Va = Actual Volume (m3)

Vt = Theoretical Volume (m3)

3.3 Material Development Factor (swell factor.

Swell Factor is the volume development that occurs in the material after excavation activities are carried out on the material. To get the swell factor you can use the formula (Peurifoy, 1998):

$$SF = \frac{D\ Losse}{D\ insitu}\ x\ 100\%$$

Description:

SF = Swell Factor

D losse = Actual Volume (m3).

D insitu = Theoretical Volume (m3).

3.4 Tool Work Efficiency.

It is an assessment of the implementation of a job in mining activities both in several fleets by working mechanical equipment where the comparison between the time used to work with the time provided.

3.5 Circulation Time for Digging Equipment and for Loading Equipment.

3.5.1 Circulation Time for Digging and Loading Equipment

It is the time used by one digging and loading equipment to complete one cycle / work cycle which consists of swing time, digging time, dumping time and empty swing time or bucket in a state of no content. So that the circular time of the digging and loading equipment can be formulated as follows (Partanto Prodjo Sumarto, 1995).

$$CTgm = Tg + Tsi + Tt + Tsk$$

Description:

Ctgm = Load digger cycle time (s).

Tg = Digging time (s).

Tsi = Load swing time (s).

Tt = Unloading time (s).

Tsk = Empty swing time (s).

3.5.2 Time to Circulate the Digging and Hauling Equipment.

The amount of time that transport takes to complete one work cycle, which includes empty maneuvering, loading, loading, dumping, and emptying, is referred to as rotation time. To formulate the transport rotation time is as follows (Prodjo Sumarto, 1995):

$$CTa = Ti + Ta + Tmd + Td + Tk + Tml$$

Description :

Cta = Dump truck cycle time (s)

Ti = Loading time (s)

Ta = Road fill time of dump truck (s)

Tmd = Load turning time of dump truck (s)

Td = Unloading time(s)

Tk = Empty road dump truck time(s)

Tml = Empty turning time (s)

3.6 Productivity

The capacity and cycle time of mechanical equipment determine productivity. The more efficient the mechanical equipment used, the more output can be produced (Nasuhi, 2017). To calculate the efficiency of each piece of equipment used for loading, transporting and excavating - for both overburden and coal.

3.5.1. Productivity of excavating equipment for coal getiing

To obtain the productivity of the digging and loading equipment for coal getting, the formula (Tenriajeng, 2003) is needed:

$$Q = \frac{\text{Kb x bff. x 3600 x effis x sf,}}{\text{Ctgm}} \text{x Densitas Batubara}$$

Description:

Q = Excavator productivity (BCM/hour)

Kb = excavator bucket loading capacity (m3)

Bff = bucket filling influence factor

Sf = swelling factor

Eff = Efficiency / work efficiency of the digging tool (%)

Ctgm = Excavator cycle time (s)

3.5.2 Haulage productivity for coal getiing.

To obtain the productivity of the conveyance for coal getting, the formula (Tenriajeng, 2003) is needed:

$$Q = \frac{n\ x\ Kb\ x\ Bff\ x360\ x\ Eff\ x\ Sf}{\text{Cta}} X\ Densitas\ batubara$$

Description :

Q = Digging and loading productivity (BCM/hour)

n = Frequency of research

Kb = bucket loading capacity (m3)

Bff = bucket fill factor

Sf = swelling factor

Eff = Efficiency / use of tool work (%)

Ctgm = cycle time of the digging and loading tool (s)

3.6 Tool Compatibility (match factor).

Match factor is where the form of equation needed to determine the equation of work compatibility for digging and loading equipment and for transport equipment that operate with each other. To determine the match factor, the formula is needed (Partanto Prodjo Sumarto, 1995):

$$Mf = \frac{Na\ x\ Ctgm\ x\ n}{Cta\ x\ Nm}$$

Description:
Mf = Match factor
Na = Number of conveyances
Ctgm = Load tool cycle time
N = number of fillings
Cta = Cycle time of conveyance
Nm = Number of loading tools

Each value of MF obtained from the formula above has a different meaning, if; If where the Match Factor equation < 1 then there is waiting time for loading transportation, meaning there is time for loading transportation to wait for the arrival of transport transportation. Match Factor = 1 then, there is harmony between loading equipment and transportation equipment. Match Factor> 1 occurs when there is a waiting time for the conveyance, meaning that there is a queue between the conveyance waiting for the loading equipment.

4 Research Methods

4.1 Literature Study.

Literature study includes reading books, research reports, and publications on the loading and transportation efficiency of excavators in order to understand ideas related to the issues to be discussed in the field.

4.2 Field Observations.

Field observations are carried out directly for several days, field observations include orientation activities with supervisors and employees who are in the field. Field observations were carried out in several places, namely MTB 1, MTB 2 (taboo) and BWE (bucket whalle excavator).

4.3 Data Collection.

4.3.1 Primary field data

Primary data is data obtained directly in the field by recording, measuring and asking directly in the field with supervisors or workers in the field. Where the data needed, among others:

1). Tool circulation time (cycle time)

It is the time used by excavation and transport equipment in completing one cycle of activity without taking into account the time constraints that occur in the field.

2). Many buckets of filling.

3). Many tools in one fleet.

4.3.2 Secondary Data.

Secondary data is data taken from several literature studies from companies, reports and results of previous publications related to the research conducted or have the same references. As for some of the secondary data data needed, namely:

1) Production data. coal

2) Rainfall data

3) Work efficiency data

4.4 Stages of Data Processing.

Data taken directly from the field which will be processed using calculations and displayed in tabular form as well as a series of processing and calculations to solve problems and get solutions in the preparation of the report.

4.5 Stages of Data Processing.

Conducted to obtain preliminary conclusions, which will be discussed further in the discussion section. After seeing how the results of data processing have been processed and correlated with the problem under study, this conclusion stages the final results that can be used to provide suggestions for each problem.

5 Results and Discussion.

5.1 Tool Work Efficiency.

5.1.1 Calculating Tool Working Hours

1). Available time in one month is February 2023 is 28 days

2) The time available in one month is:

a). Shift 1: Starting at 06.00 WIB until 18.00 WIB.

b). Shift 2: Starting at 18.00 WIB until 06.00 WIB.

3) Working time in one month is 28 x 24 hours/shift = 672 hours/month.

below is a table of tool work efficiency in 2 shifts both shift 1 and shift 2 seen in table 1 below.

Tabel 1. 1st work shift and 2nd work shift schedules.

Shift 1		
Schedule shift	Description	Time (Hours)
07.00-11.30	Operation time	4,5 hours
11.50-13.00	Break time	1,5hours (minus)
13.00-17.00	Operation time	4 hours
	Total	10 hours
Shift 2		
Schedule shift	Description	Time (Hours)

19.00-11.30	Operation time	4,5 hours
23.30-01.00	Break time	1,5 hours
01.00-05.00	Operation time	4 hours
Total		10 hours
Total Working hours		17 hours
Information on Friday prayer time 1.5 hours/week and safety talk 2 hours/week		

Description above

- Number of days in February = 28 days

- Number of hours = 24 hours/day

- Number of minutes per hour = 60 minutes/hour

- Total available working time = 17 hours/day

= 476 hours/month

= 1020 minutes/day

- Total time available in 1 month (minus Friday prayer time 6 hours/month or 360 minutes/month)

= 476-6 = 470 hours/month

- Total time available in 1 month (minus safety talk time 2 hours/month)

= 470-2= 368 hours/month

below are the avoidable barriers and the unavoidable barriers shown in table 2 below.

Tabel 2. Obstacles that can be avoided.

Hambatan	Excavator Komatsu EX269 menit/hari)	Dump Truck Hino 500 menit/hari)
1. Hambatan yang dapat di hindarkan.		
Late at the start of shift	15	20
Quit work early	10	15
Resting too long	15	15
Total	55	65
Total 28 days/month x 2 shifts	**3080**	**3640**
2. Unavoidable obstacles		
Rain	7827	7827
Tool breakage (breakdowan)	232	120
Monthly refueling (1x2) 15 minutes	210	
Refueling (1x2) 15 minutes		210
Total/minutes	8269	8157
Total Hambatan dalam 1 bulan (total 1+ total 2)		

5.2 Calculation of Productivity of PC400 Excavator in North Pit of Muara Tiga Besar Komatsu EX269 Excavator.

The following is a calculation of PC400 excavator productivity for coal loading activities..

Description :

Loading capacity (Kb) = 3 m3

Bucket fill factor (Bff) = +1

Swelling factor (Sf) = 0.8

Efficiency / tool work efficiency (Eff) = 0.67

Digging and loading equipment cycle time (Ctgm) = 28.30 seconds.

Coal density = 1.26 tons/m3.

$$Q = \frac{Kb \ x \ Bff \ x \ 3600 \ x \ Eff \ x \ Sf}{Ctgm} x \ Densitas \ Batubara$$

$$Q = \frac{3 \text{ x } 1. \text{ x } 3600. \text{ x } 0.67 \text{ x } 0.8}{28.30} \text{x } 1.26$$

$$Q = 257.73 \text{ ton/jam}$$

So, the productivity obtained from the PC400 excavator for coal getting activities is 257.73 tons/hour.

5.3 Productivity Calculation of Hino 500 Dump Truck.

The following is the calculation of the productivity of the Hino 500 dump truck conveyance for coal getting activities.

Diketahui :

Number of fills = 9

Bucket loading capacity (Kb) = 3 m3

Bucket fill factor (Bff) = 1

Swelling factor (Sf) = 0.80

Efficiency / use of tool work (Eff) = 0.67

Haulage cycle time (Cta) = 905.90 seconds

Coal density = 1.26 tons/m3.

$$Q = \frac{n \ x \ Kb \ x \ Bff \ x \ 3600 \ x \ Eff \ x \ Sf}{Ctgm} \ Densitas \ Batubara$$

$$Q = \frac{9 \ x \ 3 \ x \ 1 \ x \ 3600 \ x \ 0.67 x \ 0.80}{905.90} \ 1.26$$

$$Q = 72.46 \ ton/jam$$

So, the productivity obtained from the DT HINO 500 conveyance for coal getting activities with a distance of 2000 m is 72.46 tons / hour.

5.4 Coal Production on February 1-February 16.

Coal Production on February 1 -16 at Muara Tiga Besar 1.

Fig 5. Coal production chart 1 February-16 February

From the graph it can be seen the results of coal production on February 1 - February 16, 2023, it is known that the production target for February is 600,000 tons. With a daily production target of around 21,4286 tons and for 16 days recorded coal production results that have been achieved are 352,907.68 tons of the 28-day target. To meet the unachieved production target of 247,092.32 tons with the coal production target for the next 14 days is 17,649.45 tons / day must be met in order to achieve the production target for this February.

5.5 Match Factor Calculation.

a) Calculation of Match Factor Excavator PC400 with DT HINO 500 for Coal Getting.

The following is the calculation of the match factor of the PC400 loading excavator with the DT HINO 500 conveyance for coal getting.

Description ;

Number of conveyances (Na) = 4 units

Cycle time of loading (Ctgm) = 30.2

seconds Number of fills (n) = 9

times Cycle time of conveyance (Cta) = 905 seconds

Number of loading tools (Nm) = 1 unit.

$$MF = \frac{Na\ x\ Ctgm\ x\ n}{Cta\ x\ Nm} =$$

$$MF = \frac{4\ \text{X}\ 28.30\ \text{X}\ 9}{905.9\ \text{X}1} =$$

$$MF = 1.12$$

So, because the MF value is >1, there is a mismatch between the PC400 and DT HINO 500. The waiting time of the DT HINO 500 conveyance for the PC400 digger.

6. Conclusions and Suggestions.

6.1 Conclusions

Based on the discussion of the case study and observations made in the field, the following conclusions can be drawn:

1. In South Sumatra Province, the open pit mining method is used at PT Bukit Asam, Tbk. Tanjung Enim District, using both excavator and haul transportation equipment. In land clearing and land cleaning, stripping top soil or top soil at the beginning of stripping, stripping overburden or overburden soil, excavating and loading coal, transporting coal with dump trucks, and stockpiling coal to stockpiles that have been provided stockpiles are mining activities carried out at PT Bukit Asam, Tbk.
2. In the process of coal mining stages in the Muara Tiga Besar Mining area, the company PT Bukit Asam Tbk. uses excavator digging and loading equipment in the form of Komatsu PC 400 for coal excavation activities and Komatsu PC2000 excavators for overburden demolition, while for transportation equipment in the form of Dump Trcuk HINO 500 FM 320 TI for coal transportation activities and HD 785 for overburden.
3. The results of observations in the field obtained the productivity value of the PC400 digger for coal transportation is 257.73 tons / hour, while for DT HINO 500 FM 320 TI for coal getting is 72.46 tons / hour.
4. For the Match Factor value on the PC400 with DT HINO 500 FM 320 TI for coal getting is 1.12, meaning that there is a mismatch of the PC400 with DT HINO 500 FM because the Match Factor value is > 1. The waiting time for the DT HINO 500 FM conveyance for the PC400 digger and loader.

6.2 Suggestions.

1. Increase supervision of heavy equipment operators so that they do not drive heavy equipment too fast.
2. Pay more attention to the handling of coal combustion.
3. For washing mechanical equipment, it should be done when the equipment is standby so as not to hamper coal production activities.
4. Pay more attention to animals that can interfere with mining activities.

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